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SUBSTRATE PROCESSING APPARATUS,
SUBSTRATE PROCESSING METHOD, AND
SUBSTRATE HOLDING APPARATUS

VERIFYING DECLARATION

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Sir:

I, Tetsuya Hirosawa , declare and say:

that I am thoroughly conversant in both the Japanese and English languages;

that I am presently engaged as a translator in these languages;

that the attached document represents a true English translation of Japanese Patent Application No. 2003-289442 filed on August 7, 2003.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that there statements were made with the knowledge that willful false statements and like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signed this 20th day of February , 2009

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(NAME OF DOCUMENT) CLAIMS

(CLAIM 1)

A substrate processing apparatus for processing a substrate while supplying a fluid to the substrate, said substrate processing apparatus comprising:

a substrate holder for holding and rotating the substrate; and

a holder suction unit for sucking the fluid from said substrate holder.

(CLAIM 2)

A substrate processing apparatus, comprising:

a periphery suction unit for sucking a fluid from a peripheral portion of the substrate.

(CLAIM 3)

A substrate processing apparatus according to claim 1 or 2, wherein said substrate holder is brought into contact with the substrate so as to hold and rotate the substrate by utilizing friction between said substrate holder and the substrate.

(CLAIM 4)

A substrate processing apparatus according to claim 3, wherein said substrate holder has a clamp portion which is brought into contact with an edge portion of the substrate, and said holder suction unit is disposed close to said clamp portion so as to suck the fluid which has adhered to said clamp portion.

(CLAIM 5)

A substrate processing apparatus according to any one of claims 1 to 4, wherein said holder suction unit or said periphery suction unit communicates with a vacuum source.

(CLAIM 6)

A substrate processing apparatus according to any one of claims 1 to 5, further comprising a holder cleaning unit for supplying a cleaning fluid to said substrate holder.

(CLAIM 7)

A substrate processing apparatus according to claim 6, wherein said holder suction unit is located forward of said holder cleaning unit in a rotational direction of said substrate holder.

(CLAIM 8)

A substrate processing apparatus according to any one of claims 1 to 7, further comprising at least one gas supply nozzle provided above and/or below the substrate, said gas supply nozzle having a gas supply mouth through which a drying gas is supplied to the substrate.

(CLAIM 9)

A substrate processing apparatus according to claim 8, wherein the drying gas is an inert gas or a low humidity gas having a humidity of not more than 10 %.

(CLAIM 10)

A substrate processing apparatus according to claim 8, further comprising a heater for heating the drying gas.

(CLAIM 11)

A substrate processing apparatus according to any one of claims 8 to 10, wherein the drying gas is supplied substantially perpendicularly to a surface of the substrate.

(CLAIM 12)

A substrate processing apparatus according to any one of claims 8 to 11, further comprising a distance adjustment mechanism for adjusting a distance between said gas supply nozzle and a surface of the substrate.

(CLAIM 13)

A substrate processing apparatus according to any one of claims 8 to 12, wherein said at least one gas supply nozzle comprises a plurality of gas supply nozzles, and gas supply start timings and gas supply stop timings of said gas supply nozzles are set independently.

(CLAIM 14)

A substrate processing apparatus according to any one of claims 8 to 13, wherein said at least one gas supply nozzle comprises a plurality of gas supply nozzles, and flow rates of the drying gas supplied from said gas supply nozzles are set independently.

(CLAIM 15)

A substrate processing apparatus according to any one of claims 8 to 14, further comprising a moving mechanism for moving said gas supply nozzle between a central portion and a peripheral portion of the substrate while said gas supply nozzle supplies the drying gas to the substrate.

(CLAIM 16)

A substrate processing apparatus according to claim 15, wherein a movement speed of said gas supply nozzle is changed according to a relative position of said gas supply nozzle to the substrate.

(CLAIM 17)

A substrate processing apparatus according to claim 15 or 16, wherein said gas supply nozzle is stopped supplying the drying gas before said gas supply mouth reaches an edge portion of the substrate.

(CLAIM 18)

A substrate processing apparatus according to any one of claims 8 to 17, further comprising a monitor for monitoring a dryness of the substrate.

(CLAIM 19)

A substrate processing apparatus according to claim 18, wherein the movement speed of said gas supply nozzle is adjusted according to the dryness of the substrate.

(CLAIM 20)

A substrate processing apparatus according to any one of claims 15 to 19, further comprising a discharge port near the peripheral portion of the substrate on an extended line of the moving direction of said gas supply nozzle.

(CLAIM 21)

A substrate processing apparatus according to any one of claims 8 to 20, wherein a flow rate of the drying gas supplied from said gas supply nozzle is controlled by changing a pressure of the drying gas to be supplied from said gas supply nozzle.

(CLAIM 22)

A substrate processing apparatus according to any one of claims 1 to 21, further comprising a cleaning mechanism for cleaning the substrate.

(CLAIM 23)

A substrate processing apparatus, comprising:

a plurality of substrate processing apparatuses according to any one of claims 1 to 22.

(CLAIM 24)

A substrate processing method comprising:

rotating a substrate by a substrate holder;

supplying a fluid to the substrate being rotated; and

sucking the fluid, which has been moved from the substrate to said substrate holder, through a holder suction unit disposed close to said substrate holder.

(CLAIM 25)

A substrate processing method comprising:

sucking a fluid from a peripheral portion of a substrate through a periphery suction unit disposed close to the peripheral portion of the substrate.

(CLAIM 26)

A substrate processing method according to claim 24 or 25, wherein said substrate holder is brought into contact with an edge portion of the substrate so as to hold and rotate the substrate.

(CLAIM 27)

A substrate processing method comprising:

bringing a substrate holder into contact with an edge portion of a substrate so as to hold and rotate the substrate;

supplying a fluid to the substrate which is being rotated by said substrate holder;

supplying a drying gas to the substrate from a gas supply nozzle;

moving said gas supply nozzle from a central portion to a peripheral portion of the substrate while supplying the drying gas to the substrate so as to move the fluid on the substrate to the peripheral portion of the substrate; and

sucking the fluid, which has been moved from the peripheral portion of the substrate to said substrate holder, through a holder suction unit disposed close to said substrate holder.

(CLAIM 28)

A substrate processing method according to claim 24 or 27, further comprising:

supplying a cleaning fluid from a holder cleaning unit to said substrate holder so as to process the fluid which has been moved to said substrate holder; and

sucking the fluid, which has been processed by the cleaning fluid, through said holder suction unit;

wherein said holder suction unit is located forward of said holder cleaning unit in a rotational direction of said substrate holder.

(NAME OF DOCUMENT) SPECIFICATION

(TITLE OF THE INVENTION) SUBSTRATE PROCESSING APPARATUS AND SUBSTRATE PROCESSING METHOD

(TECHNICAL FIELD TO WHICH THE INVENTION BELONGS)

(0001)

The present invention relates to a substrate processing apparatus and a substrate processing method for performing a chemical liquid process, a cleaning process, a drying process, or the like while rotating a substrate, such as a semiconductor wafer or a liquid crystal substrate.

(BACKGROUND ART)

(0002)

In the semiconductor fabricating process, as a diameter of a semiconductor wafer becomes large, a single-wafer processing apparatus is being introduced in an increasing number of wet processes. A spin-type processing apparatus is widely known as the single wafer processing apparatus for use in a wet process, and is applied to a cleaning apparatus and a drying apparatus for a semiconductor wafer (see patent document 1 and patent document 2).

The above-mentioned spin-type processing apparatus is operated as follows. A substrate is rotated at a high speed by a substrate holder such as a spin chuck, and a chemical liquid is supplied to the substrate, which is being rotated, to clean the substrate. Thereafter, a cleaning liquid such as ultrapure water is supplied to wash out the chemical liquid, and then the substrate is rotated at a higher speed to remove the cleaning liquid, so that the substrate is dried.

During the drying process, an inert gas is supplied from a nozzle to the surface of the substrate, while the nozzle is moved from a center to a periphery of the substrate, to thereby reduce the production of water marks.

(0003)

(Patent document 1) Japanese patent publication No. 2002-52370

(Patent document 2) Japanese patent publication No. 2003-163195

(0004)

However, in the conventional processing apparatus described above, the liquid, such as the cleaning liquid, tends to remain on a portion of the substrate near the substrate holder, and hence the liquid being present near the substrate holder is not quickly replaced with a new liquid. The liquid is also likely to be scattered from the substrate holder to cause contamination of the substrate.

In a spin dry apparatus for drying a substrate by rotating the substrate at a high speed, a large amount of mist is scattered due to the high rotation. Hence, water marks are produced on a surface of a substrate. In this spin dry apparatus, although a peripheral portion of the substrate is quickly dried, a liquid on an undried area located at a central portion of the substrate tends to adhere to a dried area, i.e., the peripheral portion. Further, the liquid, which has been scattered from the peripheral portion of the substrate, bounces off a wall surface of a chamber (a processing room) and then adheres to the surface of the substrate again, producing the water marks. Furthermore, the central portion of the substrate cannot be dried sufficiently because a centrifugal force does not act on the central portion. In a case where the substrate is held by the substrate holder such as a spin chuck, a portion of the substrate near the substrate holder is not sufficiently dried. Hence, a long processing time is required to dry the substrate.

(0005)

On the other hand, it has been attempted to supply a gas from a gas supply unit to a substrate so as to dry the substrate while rotating the substrate at a high speed by a substrate holder. However, since the substrate holder such as a spin chuck, which can rotate the substrate at a high speed, is disposed underneath the substrate, it is difficult to equally dry an upper surface and a lower surface of the substrate with the gas. Specifically, when the gas is supplied to the lower surface of the substrate, it is difficult to dry the substrate without producing the water marks on the lower surface of the substrate. As described heretofore, since the conventional spin dry apparatus removes a liquid such as a cleaning liquid or a rinsing liquid from the substrate by utilizing a centrifugal force, it is difficult to dry the substrate without rotating the substrate at a high speed.

(DISCLOSURE OF THE INVENTION)

(PROBLEMS TO BE SOLBED BY THE INVENTION)

(0006)

The present invention has been made in view of the above drawbacks. It is, therefore, a first object of the present invention to provide a substrate processing apparatus and a substrate processing method which can prevent a fluid such as a processing liquid from being scattered from a substrate and a substrate holder while cleaning and drying the substrate, and can eliminate the remaining fluid on the substrate holder and can also accelerate replacement of the fluid.

It is a second object of the present invention to provide a substrate processing apparatus and a substrate processing method which can equally dry upper and lower surfaces of the substrate by supplying a gas to the substrate, can also prevent water marks from being produced on the substrate, and can dry the substrate by rotating the substrate at a low rotational speed.

(MEANS FOR COLVING THE PROBLEMS)

(0007)

In order to achieve the above objects, according to an aspect of the present invention, there is provided a substrate processing apparatus for processing a substrate while supplying a fluid to the substrate, the substrate processing apparatus comprising: a substrate holder for holding and rotating the substrate; and a holder suction unit for sucking the fluid from the substrate holder.

According to the present invention, a fluid, such as a cleaning liquid, which has adhered to the substrate holder is sucked by the holder suction unit. Therefore, a capability of replacing the fluid can be improved. Further, the fluid can be prevented from remaining on the substrate holder and from being scattered. When a cleaning process, a drying process, or other process is performed on the substrate, a part of the fluid such as the cleaning liquid is moved from the peripheral portion of the substrate to the substrate holder. According to the present invention, the fluid which has adhered to the substrate holder is sucked by the holder suction unit, and hence the sucked fluid can be recovered.

(0008)

In another aspect of the present invention, a substrate processing apparatus comprises a periphery suction unit for sucking the fluid from a peripheral portion of the substrate.

According to the present invention, the fluid on the peripheral portion of the substrate can be removed and recovered.

(0009)

In a preferred aspect of the present invention, the substrate holder is brought into contact with the substrate so as to hold and rotate the substrate by utilizing friction between the substrate holder and the substrate.

In the case of frictional rotation holder, the fluid tends to remain on the contact portion between the holder and the substrate. The fluid on the holder is also likely to scatter in the tangential direction of the holder or the substrate due to the contact with the rotating substrate. According to the present invention, the fluid on the rotating holder is sucked before the fluid contacts the substrate again. Therefore, the fluid does not adhere to the substrate again, and the scattering of the fluid is also prevented.

(0010)

In a preferred aspect of the present invention, the substrate holder has a clamp portion which is brought into contact with an edge portion of the substrate, and said holder suction unit is disposed close to said clamp portion so as to suck the fluid which has adhered to said clamp portion. The clamp portion is a portion which is brought into contact with the edge portion of the substrate to press and hold the substrate. When the substrate is rotated by the substrate holder, the fluid adheres to the clamp portion of the substrate holder. According to the present invention, since the holder suction unit is provided close to the clamp portion, the fluid can be sucked through the clamp portion with a simple structure.

(0011)

In a preferred aspect of the present invention, the holder suction unit communicates with a vacuum source. With this structure, a sufficient suction force can be obtained.

(0012)

In a preferred aspect of the present invention, the substrate processing apparatus further comprises a holder cleaning unit for supplying a cleaning fluid to the substrate holder.

According to the present invention, the fluid such as the chemical liquid which has adhered to the substrate holder can be removed more efficiently. Therefore, it is possible to prevent the chemical liquid from remaining on the substrate holder and thus prevent contamination of a next substrate which is to be processed subsequently.

(0013)

In a preferred aspect of the present invention, the holder suction unit is disposed in a position forward of the holder cleaning unit in a rotational direction of the substrate holder. With this structure, it is possible to clean the substrate holder without scattering the fluid.

(0014)

In a preferred aspect of the present invention, the substrate processing apparatus further comprises at least one gas supply nozzle provided above and/or below the substrate, said gas supply nozzle having a gas supply mouth through which a drying gas is supplied to the substrate.

A drying gas such as an inert gas (e.g., an N_2 gas) or a low humidity gas (e.g., a dry air having a humidity of not more than 10 %) is supplied from the gas supply nozzle to the substrate.

(0015)

The substrate holder which is brought into contact with the edge portion of the substrate to rotate the substrate can allow the gas supply nozzles to be disposed above and below the substrate, respectively. In contrast thereto, a spin chuck and a vacuum chuck are disposed underneath the substrate, and hence it is difficult to dispose the gas supply nozzle below the substrate.

Further, according to the present invention, since the fluid on the peripheral portion of the substrate is efficiently sucked by the holder suction unit and/or the periphery suction unit, a drying time can be shortened. Furthermore, the substrate can be dried even when the substrate is rotated at a low rotational speed and a centrifugal

force is small. When the substrate is rotated at a low speed, the scattering of the fluid is further suppressed. Therefore, the water marks can be prevented effectively from being produced on the substrate. For preventing the water marks from being produced, it is effective to eliminate moisture and oxygen. If the drying gas to be supplied to the substrate comprises an inert gas such as a nitrogen gas, the moisture and oxygen can be eliminated from an atmosphere around the substrate. Further, by supplying a low humidity gas to the substrate, it is possible to greatly prevent a mist from being produced around the substrate. According to these structures described above, the surface of the substrate can be dried at a high efficiency with a low speed rotation.

(0016)

In a preferred aspect of the present invention, the substrate processing apparatus further comprises a heater for heating the drying gas. By heating the substrate, a time required to dry the substrate can be shortened.

(0017)

In a preferred aspect of the present invention, the drying gas is supplied perpendicularly to a surface of the substrate.

If the drying gas supplied from the gas supply nozzle is obliquely incident on the substrate when drying the central portion of the substrate, a portion surrounding the central portion is dried before the central portion is dried. As a result, the fluid remaining on the central portion of the substrate adheres to the dried area, thus causing water marks. Further, if the drying gas is obliquely incident on the substrate, the drying gas impinges on a large area, and hence a drying capability is lowered. According to the present invention, since the drying gas is supplied to the substrate in the direction perpendicular to the substrate, an amount of the drying gas to be used can be reduced and an efficient drying process can be performed.

(0018)

In a preferred aspect of the present invention, the substrate processing apparatus further comprises a distance adjustment mechanism for adjusting a distance between said gas supply nozzle and a surface of the substrate.

(0019)

In a preferred aspect of the present invention, said at least one gas supply nozzle comprises a plurality of gas supply nozzles, and gas supply start timings and gas supply stop timings of said gas supply nozzles are set independently.

For preventing the water marks from being produced during the drying process of the substrate, it is important to prevent the fluid from adhering to a dried area again. Therefore, it is preferable to dry the substrate gradually from the central portion to the peripheral portion. According to the present invention, since gas supply start timings and gas supply stop timings of the gas supply nozzles are set independently so that the gas supply nozzles are started supplying the drying gas at different timings and are stopped supplying the drying gas at different timings. Therefore, the drying gas can be supplied to the substrate with a suitable amount for each position of the substrate. The supply of the drying gas may be started from the peripheral portion of the substrate in order to quickly remove the fluid remaining on the peripheral portion of the substrate.

(0020)

In a preferred aspect of the present invention, the substrate processing apparatus further comprises a gas supply unit having a plurality of gas supply nozzles for supplying a drying gas to a surface of the substrate held by the substrate holder; wherein flow rates of the drying gas supplied from the gas supply nozzles are set independently. With this structure, the drying gas can be supplied to the substrate at the flow rate suitable for each portion of the substrate.

(0021)

In a preferred aspect of the present invention, the substrate processing apparatus further comprises a moving mechanism for moving said gas supply nozzle between a central portion and a peripheral portion of the substrate while said gas supply nozzle supplies the drying gas to the substrate.

For example, by moving the gas supply nozzle from the central portion to the peripheral portion of the substrate, the fluid can be prevented from adhering again to the dried area.

(0022)

In a preferred aspect of the present invention, a movement speed of the gas

supply nozzle is changed according to a relative position of the gas supply nozzle to the substrate.

When the drying gas is supplied to the substrate from the gas supply nozzle which is being moved, the central portion of the substrate is dried within a short period of time. However, as the gas supply nozzle is moved toward the peripheral portion of the substrate, an area to be dried becomes large, and hence a longer period of time is required to dry the substrate. According to the present invention, the movement speed of the gas supply nozzle is changed according to the position thereof, so that the substrate is dried uniformly and quickly.

(0023)

In a preferred aspect of the present invention, the gas supply nozzle is stopped supplying the drying gas before the gas supply mouth reaches an edge portion of the substrate.

If the drying gas is supplied from right above or right below the peripheral portion of the substrate W, the gas and the scattered fluid enter the opposite side of the substrate, thus causing contamination and water marks. Further, if the drying gas impinges directly on an inner surface of a chamber, then the fluid, which has adhered to the inner surface of the chamber, may be scattered. According to the present invention, the gas supply nozzle is stopped supplying the drying gas immediately before the gas supply mouth thereof reaches the edge portion of the substrate. Therefore, it is possible to prevent the contamination and the scattering of the fluid and dry the substrate from the central portion to the edge portion thereof. The position at which the supply of the drying gas is stopped is preferably located radially inwardly of the edge portion of the substrate by a distance of 2 to 10 mm. After the supply of the drying gas is stopped, the gas supply nozzle is preferably moved away from the substrate in a horizontal or vertical direction.

(0024)

In a preferred aspect of the present invention, the substrate processing apparatus further comprises a monitor for monitoring a dryness of the substrate. An optical device for detecting a dryness of the substrate may be used.

(0025)

In a preferred aspect of the present invention, the movement speed of said gas supply nozzle is adjusted according to the dryness of the substrate. According to the present invention, the movement speed of the gas supply nozzle can be automatically adjusted according to the dryness of the substrate. For example, a portion of the substrate at the forward of the gas supply nozzle by a distance of 10 mm in the moving direction of the gas supply nozzle is monitored, so that if this portion is dried, then the gas supply nozzle is started to move forward. Therefore, the substrate can be dried uniformly in a short period of time.

(0026)

In a preferred aspect of the present invention, the substrate processing apparatus further comprises a discharge port near the peripheral portion of the substrate on an extended line of the moving direction of the gas supply nozzle. The drying gas, which has been used in drying the substrate, may contain a mist of the fluid such as a processing liquid which has adhered to the substrate. The drying gas, which has been used in drying the substrate, can be quickly discharged to the exterior through the discharge port, and hence the water marks can be prevented from being produced. In the chamber, flows of the drying gas are locally formed in directions from the gas supply mouth to the substrate. Therefore, the drying gas can be quickly discharged to the exterior through the discharge port after drying the substrate, and hence an atmosphere in the chamber can be prevented from being disturbed.

(0027)

In a preferred aspect of the present invention, a flow rate of the drying gas supplied from said gas supply nozzle is controlled by changing a pressure of the drying gas to be supplied from said gas supply nozzle. In a case where an aperture of the gas supply mouth is constant, the flow rate of the drying gas can be easily controlled by changing a gas supply pressure i.e., a pressure of the drying gas supplied through the gas supply mouth. If a pressure sensor for measuring the gas supply pressure is provided, the flow rate of the drying gas can be monitored by converting the measured gas supply pressure into the flow rate. A solenoid controlled valve may be provided so that the

flow rate of the drying gas is changed according to the relative position of the gas supply nozzle to the substrate during the drying process. Further, the flow rate of the drying gas to be supplied may be changed according to the type of substrate.

(0028)

In a preferred aspect of the present invention, the substrate processing apparatus further comprises a cleaning mechanism for cleaning the substrate. According to the present invention, the apparatus can perform from the cleaning process to the drying process by itself.

(0029)

In a preferred aspect of the present invention, plural substrate processing apparatuses are provided, so that the substrate processing can be performed in a shortened period of time.

(0030)

Another aspect of the present invention is a substrate processing method comprising: rotating a substrate by a substrate holder; supplying a fluid to the substrate which is being rotated; and sucking the fluid, which has been moved from the substrate to said substrate holder, through a holder suction unit disposed close to said substrate holder.

(0031)

Another aspect of the present invention is a substrate processing method comprising: sucking a fluid from a peripheral portion of a substrate through a periphery suction unit disposed close to the peripheral portion of the substrate.

(0032)

Another aspect of the present invention is a substrate processing method comprising: bringing a substrate holder into contact with an edge portion of a substrate so as to hold and rotate the substrate; supplying a fluid to the substrate which is being rotated by said substrate holder; supplying a drying gas to the substrate from a gas supply nozzle; moving said gas supply nozzle from a central portion to a peripheral portion of the substrate while supplying the drying gas to the substrate so as to move the fluid on the substrate to the peripheral portion of the substrate; and sucking the fluid, which has

been moved from the peripheral portion of the substrate to said substrate holder, through a holder suction unit disposed close to said substrate holder.

(0033)

Another aspect of the present invention is a substrate processing method according to claim 24 or 27, further comprising: supplying a cleaning fluid from a holder cleaning unit to said substrate holder so as to process the fluid which has been moved to said substrate holder; and sucking the fluid, which has been processed by the cleaning fluid, through said holder suction unit. Said holder suction unit is located forward of said holder cleaning unit in a rotational direction of said substrate holder.

(EFFECT OF THE INVENTION)

(0034)

According to the present invention, the fluid can be removed smoothly from the periphery of the substrate. The front surface and the rear surface of the present invention can be prevented from drying, and the throughput can be improved.

(BEST MODE FOR PERFORMING THE PRESENT INVENTION)

(0035)

FIG. 1 is a plan view schematically showing a substrate processing apparatus according to a first embodiment of the present invention. This substrate processing apparatus 1 comprises a chamber 10, and substrate holders 11 (11a, 11b, 11c and 11d) disposed in the chamber 10. A substrate W, such as a semiconductor wafer, is accommodated in the chamber 10, and is held and rotated by the substrate holders 11a, 11b, 11c and 11d. Holder suction nozzles (i.e., holder suction units) 24 (24a, 24b, 24c and 24d) and holder cleaning nozzles (i.e., holder cleaning units) 26 (26a, 26b, 26c and 26d) are disposed close to the substrate holders 11(11a, 11b, 11c and 11d). The holder suction nozzles 24a, 24b, 24c and 24d and the holder cleaning nozzles 26a, 26b, 26c and 26d are supported by support members 28a, 28b, 28c and 28d, respectively. Clearances between the respective holder suction nozzles 24 and the respective substrate holders 11 can be adjusted by adjusters 24', respectively, and clearances between the respective holder cleaning nozzles 26 and the respective substrate holders 11 can be adjusted by adjusters 26', respectively. Cleaning nozzles 12 and 15 are disposed at an upper surface

side and a lower surface side of the substrate W, respectively. Each of the cleaning nozzles 12 and 15 has at least one fluid supply port and at least one fluid suction port. These cleaning nozzles 12 and 15 are movable in a radial direction of the substrate W as indicated by a two-dot chain line (although a two-dot chain line indicating the cleaning nozzle 15 is not shown in the drawing).

(0036)

Gas supply nozzles 13 and 14 are disposed at the upper surface side and the lower surface side of the substrate W, respectively, so that a drying gas, such as an inert gas (e.g., an N_2 gas) or a dry air having a humidity of not more than 10 %, is supplied from each of the gas supply nozzles 13 and 14 to the substrate W. The gas supply nozzles 13 and 14 have gas supply mouths 17 and 18, respectively. Each of these gas supply nozzles 13 and 14 is swingable about a fulcrum C in the substantially radial direction of the substrate W as indicated by a chain line in the drawing. The substrate processing apparatus also comprises a bevel suction nozzle 16 serving as a periphery suction unit for sucking a fluid (e.g., liquid) on a peripheral portion of the substrate W. Although the four substrate holders 11 are provided in this embodiment as shown in the drawing, the number of substrate holders 11 is not limited to four, and three or more substrate holders may be provided. Examples of the fluid to be supplied from the cleaning nozzles 12 and 15 include a cleaning fluid, an etching liquid, and an etching gas. Specifically, a corrosive gas (e.g. hydrogen fluoride), an acid (e.g. fluorinated acid), an oxidizing agent (e.g. hydrogen peroxide, nitric acid, or ozone), an alkaline agent (e.g. ammonia), a chelating agent, a surface active agent, or a combination of these may be used.

(0037)

FIGS. 2(a) and 2(b) are views showing a structure of the substrate holder. The substrate holders (rotating holders) 11 for holding the substrate W comprise rollers 20, respectively, and each of the rollers 20 has a clamp portion 21 formed on its circumferential surface. The rollers 20 are brought into contact with an edge portion of the substrate W under predetermined pressing forces which are toward a substantially center of the substrate W. All the substrate holders 11 are rotated by at least one

rotating mechanism such as a motor (not shown) at a predetermined rotational speed in the same direction. The substrate holders 11 impart a rotational force to the substrate W due to friction between the substrate holders 11 and the edge portion of the substrate W while holding the substrate W. At least one of the substrate holders 11 may be rotated by the rotating mechanism. The holder suction nozzles 24 are disposed close to the clamp portions 21 of the rollers 20, respectively, and each of the holder suction nozzles 24 has a suction mouth 23 for sucking a fluid such as a processing liquid. The suction mouth 23 is positioned close to the clamp portion 21 with a distance of not more than 5 mm, for example, so as to suck the fluid that has adhered to the clamp portion 21. Similarly, the holder cleaning nozzles 26 are disposed close to the clamp portions 21 of the rollers 20, respectively, and each of the holder cleaning nozzles 26 has a supply mouth 25 for supplying a cleaning fluid such as a cleaning liquid to the clamp portion 21. The rollers 20 are made of PVDF (polyvinylidene fluoride) which is a fluororesin having a chemical resistance.

(0038)

In a case of using a spin chuck which holds a substrate fixedly, a fluid being present at an inward side of an unguis of the spin chuck is not easily replaced with a new fluid. In contrast thereto, in this embodiment, the substrate W is held and rotated by the rollers 20 of the respective substrate holders 11a, 11b, 11c and 11d, and the holder suction nozzles 24a, 24b, 24c and 24d are provided close to the substrate holders 11a, 11b, 11c and 11d so as to suck the fluid on the substrate holders 11a, 11b, 11c and 11d. Therefore, it is possible to accelerate the replacement of the fluid near the substrate holders 11a, 11b, 11c and 11d and prevent the liquid from remaining on the substrate W and the substrate holders 11a, 11b, 11c and 11d.

The clamp portions 21 of the substrate holders 11 are brought into contact with the edge portion of the substrate W to press the substrate W toward an inward side of the substrate W under the predetermined pressing forces. It is preferable that the clamp portions 21 have a recessed shape so that the substrate W is not disengaged from the clamp portions 21 while being held and rotated. It is also preferable that the clamp portions 21 have a complete round shape as viewed from right above. The clearance

between the holder suction nozzle 24 and the clamp portion 21 is preferably not more than 1 mm, more preferably not more than 0.5 mm. The rollers 20 should preferably be made of a fluororesin such as PVDF or PEEK, which has a chemical resistance, or polyurethane. The clearance (positional relationship) between the holder cleaning nozzle 26 and the clamp portion 21 is preferably not more than 1 mm, more preferably not more than 0.5 mm, as with the clearance between the holder suction nozzle 24 and the clamp portion 21.

(0039)

If the holder suction nozzle 24 is not provided, a fluid that has adhered to the clamp portion 21 is brought into contact with the substrate W again by the rotation of the roller 20, and the fluid is thus scattered in tangential directions X of the substrate W and the roller 20 (see FIG. 2(a)). In order to prevent such a scattering of the fluid, the suction mouth 23 and the supply mouth 25 are arranged as follows: If the roller 20 is rotated in a direction indicated by arrow in FIG. 2(a), the holder cleaning nozzle 26 having the supply mouth 25 is positioned at the forward of a contact portion Wc between the clamp portion 21 and the substrate W in the rotational direction of the roller 20. Further, the holder suction nozzle 24 having the suction mouth 23 is positioned at the forward of the holder cleaning nozzle 26 in the rotational direction of the roller 20. When the roller 20 is rotated in the direction indicated by the arrow in FIG. 2(a), the fluid on the peripheral portion of the substrate W is moved to the clamp portion 21 of the roller 20 via the contact portion Wc, and then the clamp portion 21 to which the fluid has adhered is cleaned with the cleaning fluid supplied from the supply mouth 25 of the holder cleaning nozzle 26. As the roller 20 is rotated, the fluid, which has been processed by the cleaning fluid, reaches in front of the suction mouth 23 of the holder suction nozzle 24, and is then sucked by the holder suction nozzle 24. This arrangement can prevent the fluid from being scattered from the peripheral portion of the substrate W. Therefore, it is possible to prevent contamination of the substrate W and prevent water marks from being produced. Further, because the fluid on the peripheral portion of the substrate W is sucked by the bevel suction nozzle 16, the fluid can be removed from the peripheral portion of the substrate W even when the substrate W is

rotated at a low rotational speed.

(0040)

As shown in FIG. 2(c), a suction passage 27 may be provided inside the roller 20 so that the fluid such as a liquid is sucked through one or more open mouths which open at the clamp portion 21 and communicate with the suction passage 27. Although the above-mentioned embodiment shows an example in which the holder cleaning nozzle 26 is provided, if the cleaning process is not required, it is possible to dispense with the holder cleaning nozzle 26. Both the suction mouth 23 and the suction passage 27 communicate with a vacuum source through a gas-liquid separator, so that the fluid is sucked by the vacuum source. An ejector or a vacuum pump may be used as the vacuum source.

(0041)

FIGS. 3(a) and 3(b) are views illustrating an effect of the holder suction nozzle disposed close to the substrate holder. Specifically, FIG. 3(a) shows a case where the holder suction nozzle is not provided. In this case, a fluid D remaining on the peripheral portion is moved to the clamp portion 21 as indicated by signs D', D" as the roller 20 and the substrate W are rotated. On the other hand, FIG. 3(b) shows a case where the holder suction nozzle is provided. In this case, the fluid D on the peripheral portion of the substrate W is moved to the clamp portion 21 of the roller 20 as indicated by the sign D' and then sucked by the above-mentioned holder suction nozzle 24. In this manner, the fluid on the substrate W is sucked smoothly by the holder suction nozzle 24 through the clamp portion 21 of the roller 20, and hence an amount of the fluid D remaining on the substrate W can be greatly reduced. Therefore, it is possible to promote the replacement of the fluid and prevent the remaining and scattering of the fluid.

(0042)

FIG. 4 is a schematic view showing evacuation paths of the holder suction nozzles and the bevel suction nozzle. As shown in FIG. 4, both the bevel suction nozzle 16 and the holder suction nozzles 24 are connected to a gas-liquid separator 31 and are further connected to a vacuum source (ejector) 32 through the gas-liquid separator 31.

(0043)

According to the substrate processing apparatus of this embodiment, the fluid remaining on the peripheral portion of the substrate can be removed even when the substrate is rotated at a low rotational speed of not more than 500 min^{-1} and a centrifugal force is small. Therefore, when the cleaning process is performed, a uniform film of a cleaning liquid can be formed over the surface of the substrate, and hence the substrate can be uniformly cleaned. Further, the substrate can be quickly dried. Generally, in a case where a substrate is held and rotated by the substrate holder having the roller, a fluid is likely to remain on a contact portion between the substrate holder and the substrate. In addition, the fluid which has adhered to the substrate holder tends to be scattered in the direction tangent to the substrate holder or the substrate due to contact with the substrate which is being rotated. According to the substrate processing apparatus of this embodiment, the fluid which has adhered to the substrate holder is sucked by the holder suction nozzle 24 before the fluid goes round to be brought into contact with the substrate again. Therefore, the old fluid that has been used in the processing does not adhere to the substrate again. Further, the scattering of the fluid is greatly suppressed because of the low-speed rotation. When the substrate is rotated at a low rotational speed of not more than 500 min^{-1}, particularly around 100 min^{-1}, an excellent effect can be obtained such that the fluid is prevented from being scattered and the replacement of the fluid is improved. However, this substrate processing apparatus is not limited to a low-speed rotating operation.

The bevel suction nozzle 16 is disposed close to the peripheral portion of the substrate W and sucks the fluid on the peripheral portion (the bevel portion) of the substrate W. A clearance between the bevel suction nozzle 16 and the surface, e.g., the peripheral portion, of the substrate W is preferably not more than 1 mm, more preferably not more than 0.5 mm. It is preferable that the bevel suction nozzle 16 is disposed close to an upper section, a side edge section, or a lower section of the peripheral portion of the substrate W. Two or more bevel suction nozzles may be disposed close to at least two of the upper section, the side edge section, and the lower section of the peripheral portion of the substrate W.

(0044)

FIG. 5 is a side view showing an example in which the gas supply nozzles 13 and 14 are disposed above and below the substrate W which is held and rotated by the rollers 20 of the substrate holders 11 and a drying gas is supplied from the gas supply mouths 17 and 18 of the gas supply nozzles 13 and 14 to the upper surface and the lower surface of the substrate W. Specifically, in this embodiment, the gas supply nozzle 13, which is swingable in the radial direction of the substrate W, is disposed at the upper surface side of the substrate W, and the swingable gas supply nozzle 14 is disposed at the lower surface side of the substrate W. Although this embodiment shows an example in which the gas supply nozzles 13 and 14 are disposed at the upper and lower surface sides of the substrate W, respectively, the gas supply nozzle may be disposed at either the upper surface side or the lower surface side of the substrate W. A drying gas such as an inert gas (e.g., an N_2 gas) or a low humidity gas (e.g., a dry air having a humidity of not more than 10 %) is supplied from each of the gas supply nozzles 13 and 14 to the substrate W.

(0045)

It is preferable to provide a heater for heating a drying gas to be ejected from the gas supply nozzles 13 and 14. With this structure, the drying gas which has been heated can be supplied to the substrate W for thereby drying the substrate W. Specifically, by supplying the heated drying gas to the surface of the substrate W, the drying of the substrate W can be accelerated. Generally, when a gas is supplied to a wet substrate, a temperature of the substrate is lowered due to heat of vaporization. By heating the gas and then supplying the heated gas to the substrate, a drying time of the substrate can be shortened.

(0046)

The substrate holders 11 rotate the substrate W by utilizing friction between the substrate W and the clamp portions 21 of the rollers 20 which are held in contact with the edge portion of the substrate W. According to such substrate holders 11, the gas supply nozzles 13 and 14 can be disposed near the upper and lower surfaces of the substrate W. In a case of a spin-chuck-type substrate holder, a spin chuck should be disposed

underneath a substrate, and hence the spin chuck makes it difficult to dispose a swingable gas supply nozzle near a lower surface of the substrate. Accordingly, the spin-chuck-type substrate holder having no gas supply nozzle cannot dry the substrate with a low speed rotation. Thus, the spin-chuck-type substrate holder is required to be operated at a high rotational speed for drying the substrate, and hence the water marks tend to be produced by the fluid which is scattered due to a high speed rotation. In contrast thereto, in this embodiment, the substrate W is held by the rollers 20 in a point contact manner, i.e., a rolling contact manner, and the bevel suction nozzle 16 and the holder suction nozzle 24 are provided so as to suck the fluid. Therefore, even when the substrate W is rotated at a low speed, the fluid on the peripheral portion of the substrate W can be removed efficiently. Accordingly, the dying time can be shortened. Further, since only a small amount of the fluid is scattered, the water marks can be prevented from being produced on the substrate W. For preventing the water marks from being produced on the substrate, it is effective to eliminate moisture and oxygen from an atmosphere around the substrate. In this embodiment, an inert gas, such as an N_2 gas, or a low humidity gas having a humidity of not more than 10 % is supplied to the substrate, and hence moisture and oxygen can be eliminated effectively. According to such a drying process, it is possible to dry the substrate efficiently without rotating the substrate at a high speed and prevent the fluid from being scattered.

(0047)

If a drying gas is obliquely incident on the substrate when drying a central portion of a substrate, an area surrounding the central portion of the substrate is dried more quickly than the central portion. As a result, a fluid remaining on the central portion of the substrate is likely to adhere to the dried area, thus causing water marks. Further, if the drying gas is obliquely incident on the substrate, the drying gas impinges on a large area, and hence a drying capability is lowered. Therefore, it is preferable that the drying gas is supplied perpendicularly to the substrate. From this viewpoint, the gas supply nozzles 13 and 14 are disposed perpendicularly to the substrate W. Therefore, each of the gas supply mouths 17 and 18 of the gas supply nozzles 13 and 14 supplies the drying gas in a direction perpendicular to the surface of the substrate W.

(0048)

A distance between the gas supply mouth 17 and the upper surface of the substrate W and a distance between the gas supply mouth 18 and the lower surface of the substrate W are adjusted by distance adjustment mechanisms, respectively. As shown in FIG. 5, when the gas supply nozzles 13 and 14 are about to supply the drying gas, the gas supply nozzles 13 and 14 are moved to positions close to the upper and lower surfaces of the substrate W as indicated by two-dot chain lines. In order to increase a drying capability, it is preferable to shorten a period of time when the substrate is transited from a wet state to a dried state, i.e., a period of time of being in a semi-dried state. Therefore, it is preferable to quickly dry a small area with a vigorously ejected drying gas, rather than to slowly dry a large area with a weakly ejected drying gas. If the gas supply mouths 17 and 18 are positioned away from the substrate W, the drying gas is dispersed as it travels. For this reason, the gas supply nozzles 13 and 14 should preferably be positioned close to the substrate W when supplying the drying gas. Specifically, a distance between the substrate W and each of the gas supply mouths 17 and 18 is preferably in the range of 30 to 50 mm, more preferably in the range of 3 to 10 mm. It is also preferable that the drying gas ejected from the gas supply mouths 17 and 18 does not spread as the drying gas travels toward the substrate W. When a cleaning process is to be performed by supplying a cleaning liquid, the gas supply nozzles 13 and 14 are required to be moved away from the substrate W. From this viewpoint, the gas supply nozzles 13 and 14 are required to be movable with a sufficient distance. The important one of the gas supply conditions for drying the substrate is a gas velocity. When the gas supply mouth 17 (or 18) is positioned close to the substrate W, a desirable gas velocity at the gas supply mouth 17 (or 18) is in the range of 10 to 3,000 m/s. The gas velocity at the gas supply mouth can be calculated based on a supply amount of the fluid and an exit area of the gas supply mouth. Specifically, in a case where an object to be dried is a hydrophobic film, the gas velocity is preferably in the range of 10 to 300 m/s, and in a case where the object to be dried is a hydrophilic film, the gas velocity is preferably in the range of 400 to 1,000 m/s.

(0049)

In the substrate processing apparatus of this embodiment, the upper-surface-side gas supply nozzle 13 and the lower-surface-side gas supply nozzle 14 are movable between the central portion and the peripheral portion of the substrate W in the radial direction of the substrate W as indicated by the arrows A in FIG. 5. By moving the gas supply nozzles 13 and 14 from the central portion to the peripheral portion of the substrate W, the substrate W can be dried gradually from the central portion to the peripheral portion of the substrate W. Specifically, while the substrate W is held and rotated by the substrate holders 11, the drying gas is supplied from the gas supply nozzles 13 and 14 to the substrate W, and the gas supply nozzles 13 and 14 are moved from the central portion to the peripheral portion of the substrate W while supplying the drying gas, so that the fluid on the substrate W is moved toward the peripheral portion of the substrate W. The fluid, which has been moved to the peripheral portion of the substrate W, is then sucked by the bevel suction nozzle (periphery suction unit) 16. The fluid is further moved to the substrate holders 11 which are held in contact with the edge portion of the substrate W, and is then sucked and removed by the holder suction nozzles.

(0050)

As shown in FIG. 6(a), instead of using the swingable gas supply nozzles 13 and 14, a circular-plate-like gas supply unit having a plurality of gas supply nozzles a to c4 and having substantially the same diameter as the substrate W may be disposed at the upper surface side or the lower surface side of the substrate W. In this case, a supply start timing and a supply stop timing of the drying gas from the gas supply nozzles a to c4 are set independently of each other so that the respective gas supply nozzles a to c4 can start supplying the drying gas and stop supplying the drying gas at different timings. Flow rates of the drying gas supplied from the gas supply nozzles a to c4 may also be set independently of each other. For example, the gas supply nozzle a facing the central portion of the substrate W supplies the drying gas at a low flow rate, the gas supply nozzles b1, b2, b3 and b4 facing an intermediate portion of the substrate W supply the drying gas at a higher flow rate than that of the gas supply nozzle a, and the gas supply nozzles c1, c2, c3 and c4 facing the peripheral portion of the substrate W supply the drying gas at a higher flow rate than that of the gas supply nozzles b1, b2, b3 and b4.

With this structure, even if object areas to be dried by the gas supply nozzles are different from each other, the entire surface of the substrate can be dried uniformly.

Open-close timings of valves communicating with the respective gas supply nozzles a to c4 may be controlled independently. For example, as shown in FIG. 6(b), the valves are opened in such a manner that the gas supply nozzle a, the gas supply nozzles b, and the gas supply nozzles c start supplying the drying gas in this order, and the valves are closed in such a manner that the gas supply nozzle a, the gas supply nozzles b, and the gas supply nozzles c stop supplying the drying gas in this order. With this structure, the drying gas can be supplied to the substrate in the order of the central portion, the intermediate portion, and the peripheral portion of the substrate while the substrate is being rotated, and hence the fluid on the substrate can be moved to the peripheral portion of the substrate. In this manner, by moving the fluid on the substrate to the peripheral portion of the substrate, it is possible to securely prevent the fluid from adhering to the dried area. In order to quickly remove the fluid remaining on the peripheral portion of the substrate, the gas supply nozzles c1, c2, c3 and c4 may first start supplying the drying gas to the peripheral portion of the substrate, as shown in FIG. 6(c).

(0051)

The gas supply nozzles 13 and 14 are moved in the radial direction of the substrate W by moving mechanisms (not shown). These moving mechanisms can change the movement speeds of the gas supply nozzles 13 and 14 according to the radial positions of the gas supply nozzles 13 and 14. When the drying gas is supplied from the gas supply nozzles 13 and 14 to the substrate W in rotation, the central portion is quickly dried. However, as the gas supply nozzles 13 and 14 are moved to the peripheral portion of the substrate W, an area to be dried is increased, and hence it takes much time to dry the substrate W. FIG. 7(a) shows a time chart illustrating a movement speed and a gas supply timing of the gas supply nozzle. As shown in FIG. 7(a), the movement speed of the gas supply nozzle is high at the central portion of the substrate W, and is gradually decreased as the gas supply nozzle is moved to the peripheral portion of the substrate W. Specifically, the following relation holds the movement speed V_1 at the central portion, the movement speed V_2 at the intermediate portion, and the movement

speed V_3 at the peripheral portion:

$$V_1 > V_2 > V_3$$

In this manner, the movement speeds of the gas supply nozzles which are moved in the radial direction of the substrate W are changed according to the relative positions to the substrate W. Specifically, when the gas supply nozzles 13 and 14 face a small area to be dried, i.e., the central portion of the substrate W, the gas supply nozzles 13 and 14 are moved at a high movement speed V_1, and as the gas supply nozzles 13 and 14 are moved toward the peripheral portion, which has a large area, of the substrate W, the movement speeds of the gas supply nozzles 13 and 14 are reduced to V_2, and then to V_3. Accordingly, an amount of the drying gas that has been supplied per unit area can be uniform over the entire surface of the substrate W, and hence the substrate W can be dried uniformly. It is also possible to prevent the fluid from adhering to the dried area. As shown in FIG. 7(b), a gas supply pressure P_1 may be set to be low at the central portion of the substrate W and may be increased to P_2 when the gas supply nozzles 13 and 14 are moved toward the peripheral portion of the substrate W. In FIGS. 7(a) and 7(b), a time T_1 at which the supply of the gas is stopped indicates a time point when the gas supply mouth passes a portion positioned radially inwardly of the edge portion of the substrate W by a distance of 2 to 10 mm, and a time T_2 indicates a time point when the gas supply mouth passes the edge portion of the substrate W. Both the movement speeds and the gas supply pressures of the gas supply nozzles 13 and 14 may be changed simultaneously.

(0052)

Generally, when a substrate is dried, a color of a surface thereof is changed. Specifically, as a thickness of a liquid film on the surface of the substrate is changed, the manner of reflection of a light is changed. Therefore, there is a difference in color of the surface between the wet substrate and the dried substrate. It is preferable that the substrate processing apparatus has an optical device (e.g., a CCD, a reflectiometer, an interference-type optical measuring device) for detecting a dryness of the substrate. A monitor may be provided for monitoring the dryness of the substrate so that the movement speeds of the gas supply nozzles 13 and 14 are automatically adjusted

according to the dryness of the substrate. For example, a portion of the substrate at the forward of the gas supply nozzle by a distance of 10 mm in the moving direction of the gas supply nozzle is monitored so that if the color of this portion is changed into a preset color to indicate the dried state, then the gas supply nozzle is started to be moved toward the peripheral portion of the substrate W. According to such a control process, even if areas of the object portions to be dried vary as the gas supply nozzles 13 and 14 are moved in the radial direction of the substrate W, the substrate W can be dried uniformly.

(0053)

As shown in FIG. 8(a), if a gas is supplied from right above or right below the peripheral portion of the substrate W, gas turbulence occurs at the edge portion of the substrate W. As a result, the fluid such as a processing liquid is scattered from the substrate W or the substrate holders 11 and then enters the opposite side the substrate W, thus causing contamination and water marks. Further, as shown in FIG. 8(c), if the gas impinges directly on the inner surface of the chamber 10, the fluid and particles on the inner surface of the chamber 10 are scattered around. Furthermore, if the supply of the gas is stopped at a position far away from the edge portion of the substrate W, then the edge portion of the substrate W cannot be dried sufficiently, and if the gas is supplied from right above or right below the edge portion of the substrate W, then the fluid is also scattered. As described above, the time T_2 in FIGS. 7(a) and 7(b) is a time point at which the gas supply mouth 17 (or 18) passes the edge portion of the substrate W. Since the gas supply nozzle 13 (or 14) is stopped supplying the drying gas at the time T_1, i.e., immediately before the gas supply mouth 17 (or 18) reaches the edge portion of the substrate W, it is possible to prevent the fluid from being scattered from the edge portion of the substrate W and prevent the contamination of the substrate W. From these viewpoints, the position at which the supply of the drying gas is to be stopped is preferably located radially inwardly of the edge portion of the substrate W by a distance of 2 to 10 mm. After being stopped supplying the drying gas, the gas supply nozzles 13 and 14 are preferably moved away from the substrate W.

(0054)

As shown in FIG. 8(b), it is preferable to provide discharge ports 33 near the

peripheral portion of the substrate W on extended lines of the moving directions of the gas supply nozzles 13 and 14. Specifically, the drying gas, which has been used in drying the substrate W, may contain a mist of the fluid such as a processing liquid which has adhered to the substrate W. According to the discharge ports 33 shown in FIG. 8B, the drying gas, which has been used in drying the substrate W, can be quickly discharged to the exterior through the discharge ports 33, and hence the water marks can be prevented from being produced. In the chamber 10, flows of the drying gas are locally formed in directions from the gas supply mouths 17 and 18 to the substrate W. Therefore, the drying gas can be quickly discharged to the exterior through the discharge ports 33 after drying the substrate W, and hence an atmosphere in the chamber 10 can be prevented from being disturbed. If inside diameters of the gas supply nozzles 13 and 14 are constant, a flow rate (i.e., a flow velocity) of the drying gas can be easily controlled by changing a gas supply pressure i.e., a pressure of the drying gas supplied from each of the gas supply mouths 17 and 18. A pressure sensor for measuring the gas supply pressure may be provided so as to control the flow rate (i.e., the flow velocity) of the drying gas by controlling the gas supply pressure. As shown in FIG. 7(b), the gas supply pressure may be set to low initially, and may be increased when the gas supply nozzles 13 and 14 reach predetermined positions. Drying conditions such as the rotational speed of the substrate W, the distances between the surfaces of the substrate W and the gas supply nozzles 13 and 14, the movement speeds of the gas supply nozzles 13 and 14, and the gas supply pressure may be set in advance according to the type of substrate (wafer) or film formed on the surface of the substrate. In this case, measured values corresponding to the respective drying conditions are monitored during the drying process. The measured values are compared with preset data of the drying conditions, and the drying process of the substrate is controlled in such a manner that the measured values are kept equal to the preset data.

(0055)

FIG. 9 is a plan view showing a substrate processing apparatus according to a second embodiment of the present invention, and FIG. 10 is side view showing the substrate processing apparatus shown in FIG. 9. Like or corresponding parts of this

embodiment are denoted by the same reference numerals as those in the first embodiment, and will not be described below repetitively.

This substrate processing apparatus 1' comprises a chamber 10, and substrate holders 11a, 11b, 11c and 11d disposed in the chamber 10. A substrate W such as a semiconductor wafer is accommodated in the chamber 10, and is held and rotated by the substrate holders 11a, 11b, 11c and 11d. The respective substrate holders 11a, 11b, 11c and 11d have holder suction nozzles and holder cleaning nozzles, both of which are disposed close to the substrate holders 11a, 11b, 11c and 11d. When a processing fluid such as a chemical liquid is supplied onto a surface of the substrate W, the processing fluid is moved from a peripheral portion of the substrate W the to the substrate holders 11a, 11b, 11c and 11d while the substrate W is being processed, e.g., cleaned or etched. The processing fluid, which has been moved to the substrate holders 11a, 11b, 11c and 11d, is processed by a cleaning liquid supplied from holder cleaning nozzles, and then sucked by holder suction nozzles.

The substrate processing apparatus 1' further comprises gas supply nozzles 13 and 14 so that a drying gas is supplied from each of gas supply mouths 17 and 18 of the gas supply nozzles 13 and 14 to the substrate W for thereby drying the upper surface and the lower surface of the substrate W. The substrate processing apparatus 1' further comprises a bevel suction nozzle 16 for sucking a processing fluid on a peripheral portion (a bevel portion) of the substrate W. Although not shown in FIG. 9, the substrate processing apparatus 1' comprises cleaning nozzles (see reference numerals 12 and 15 in FIG. 1). In order to promote the drying of the peripheral portion of the substrate W and prevent water marks from being produced, the holder cleaning nozzles do not supply the cleaning liquid during the drying process, as with the above-mentioned substrate processing apparatus 1.

(0056)

The substrate processing apparatus 1' further comprises sponge roll type cleaning tools 29a and 29b for cleaning the upper and lower surfaces of the substrate W. The substrate processing apparatus 1' performs a cleaning process as follows: While the cleaning liquid is supplied from the non-illustrated cleaning nozzles to the upper and

lower surfaces of the substrate W, the sponge roll type cleaning tools 29a and 29b are rotated about their own axes and brought into sliding contact with the upper and lower surfaces of the substrate W, thereby scrubbing the upper and lower surfaces of the substrate W rotated by the substrate holders 11a, 11b, 11c and 11d. After cleaning the substrate W, the sponge roll type cleaning tools 29a and 29b are retreated to retreat positions, respectively, as indicated by two-dot chain lines in FIG. 10. Thereafter, the gas supply nozzles 13 and 14 are moved close to the substrate W and then supply the drying gas to the upper and lower surfaces of the substrate W to dry the substrate W.

At least one sponge roll type cleaning tool for scrubbing the peripheral portion of the substrate W may be provided in the substrate processing apparatus 1'. In this case, this sponge roll type cleaning tool is rotated about its own axis extending perpendicularly to the surface of the substrate W and is brought into sliding contact with the peripheral portion of the substrate W which is being rotated. In the scrubbing process, the sponge roll type cleaning tools 29a and 29b for scrubbing the upper and lower surfaces of the substrate W and the above-mentioned sponge roll type cleaning tool for scrubbing the peripheral portion of the substrate W may be operated simultaneously to clean the substrate W. A cleaning liquid to which ultrasonic wave has been applied may be supplied from fluid supply ports of the cleaning nozzles (see the reference numerals 12 and 15 in FIG. 1) to the upper and lower surfaces of the substrate W to perform an ultrasonic cleaning process, and the used cleaning liquid may be sucked by fluid suction ports of the cleaning nozzles. The scrubbing process and the ultrasonic cleaning process may be performed simultaneously.

Preferable operation flow of the substrate processing apparatus 1' is as follows: Etching process → cleaning process with a chemical liquid or ultrasonic cleaning process → rinsing process → scrubbing process → rinsing process → drying process. Other preferable operation flow is as follows: Etching process → a first cleaning process with a chemical liquid or a first ultrasonic cleaning process → rinsing process → scrubbing process → a second cleaning process with a chemical liquid or a second ultrasonic cleaning process → rinsing process → drying process. In this manner, the substrate processing apparatus 1' can perform several processes by itself. According to the

substrate processing apparatus 1', it is possible to prevent the processing fluid from being scattered from the substrate holders and perform a variety of processes without producing the water marks on the substrate.

(0057)

FIG. 11 is a schematic plan view showing a substrate processing system incorporating the substrate processing apparatus 1 or 1'. As shown in FIG. 11, the substrate processing system 71 comprises two wafer cassettes 81A and 81B for accommodating a plurality of substrates W such as semiconductor wafers therein, a plating apparatus 84 for plating the substrate W, an etching apparatus 82 for etching the substrate W, and the substrate processing apparatus 1 or 1' for cleaning and drying the substrate W which has been etched. The substrate processing system 71 further comprises a first transfer robot 85A and a second transfer robot 85B for transferring the substrate W from one to another of the above-mentioned apparatuses. The substrate processing system 71 further comprises a buffer stage 86 having upper and lower shelves on which the two substrates W are temporarily placed separately when the substrate W is transferred between the first transfer robot 85A and the second transfer robot 85B. In this substrate processing system 71, either of the plating apparatus 84 and the etching apparatus 82 is a single-wafer processing apparatus which processes the substrate one by one, as with the substrate processing apparatus 1 or 1'.

(0058)

Each of the wafer cassettes 81A and 81B has a plurality of shelves (not shown) so that the substrates W are accommodated in the shelves, respectively. One of the substrates W accommodated in the wafer cassette 81A (or 81B) is removed by the first transfer robot 85A, and is transferred to the second transfer robot 85B via the buffer stage 86. The substrate W is transferred to the plating apparatus 84 by the second transfer robot 85B, and is then plated in the plating apparatus 84. Next, the substrate W is transferred to the etching apparatus 82, and is then etched in the etching apparatus 82.

The etching apparatus 82 may be constructed to have the same structure as the substrate processing apparatus 1 or 1' so that the cleaning nozzles 12 and 15 (see FIG. 1) supply an etching liquid instead of supplying a cleaning liquid. Alternatively, the

substrate processing apparatus 1 or 1' may perform an etching process, a cleaning process, and a drying process, without providing the etching apparatus 82. The etching apparatus 82 may be replaced with the substrate processing apparatus 1 or 1' so that the two substrate processing apparatuses 1 or 1' perform the etching process, the cleaning process, and the drying process simultaneously. With this arrangement, in a case where a processing time of the plating apparatus 84 is shorter than that of the substrate processing apparatus 1, the two substrate processing apparatuses 1 or 1' are operated simultaneously (i.e., in a parallel processing manner) for thereby improving a processing capability (through put) of the substrate processing system 71.

(0059)

After the etching process is performed by the etching apparatus 82, the substrate W is transferred to the substrate processing apparatus 1 by the second transfer robot 85B. In the substrate processing apparatus 1, the processing fluid is supplied to and sucked from the upper and lower surfaces of the substrate W by the cleaning nozzles 12 and 15 while the substrate W is held and rotated in the manner as described above, thereby cleaning the upper surface and the lower surface of the substrate W. Accordingly, reaction products that have been produced by the etching process are washed out by the substrate processing apparatus 1. Particularly, fine particles on the surface and fine particles in recesses of the surface of the substrate W are removed. Two step cleaning process may be performed by the substrate processing apparatus 1 or 1'. Specifically, a first cleaning process may be performed with use of an acid cleaning liquid such as fluorinated acid, and a second cleaning process may be performed with use of an alkaline cleaning liquid.

(0060)

After the cleaning process, the drying gas is supplied from the gas supply nozzles 13 and 14 (see FIG. 1) to the upper and lower surfaces of the substrate W, thereby drying the substrate W which has been cleaned. The dried substrate W is successively transferred from the substrate processing apparatus 1 to the wafer cassette 81A (or 81B) by the second transfer robot 85B and the first transfer robot 85A through the buffer stage 86. The substrate W is then accommodated in the wafer cassette 81A or

81B, and a sequence of the processes is thus completed. In this manner, the substrate processing apparatus 1 or 1' according to the embodiment is suitable for use in the substrate processing system 71 which performs various kinds of processes such as the plating process, the etching process, the cleaning process, and the drying process. Particularly, the substrate processing apparatus 1 or 1' can perform the cleaning process and the drying process at a high efficiency and a high quality. The substrate processing apparatus 1 or 1' can also shorten an operation time and can contribute to the improvement of a yield of products.

In this substrate processing system 71, the etching apparatus 82 and the plating apparatus 84 may be replaced with a bevel etching apparatus for etching a bevel portion of the substrate, a bevel polishing apparatus for polishing the bevel portion of the substrate, an electrolytic polishing apparatus for performing an electrolytic polishing on a plated layer or the like, or a CMP apparatus for performing a chemical mechanical polishing on the surface of the substrate. Alternatively, the etching apparatus 82 and the plating apparatus 84 may be replaced with the substrate processing apparatuses 1 or 1', respectively, so that the substrate processing system 71 has three substrate processing apparatuses 1 or 1' for performing the etching process and/or the cleaning process and the drying process simultaneously.

(0061)

Although the preferred embodiments of the present invention have been described above, the present invention is not limited to the above embodiments, but may be practiced in various forms within the scope of the technical concept thereof. The present invention is not limited to the illustrated embodiments, but various changes may be made therein without departing from the scope of the invention.

(BRIEF DESCRIPTION OF DRAWINGS)

(0062)

(FIG. 1) FIG. 1 is a plan view showing a substrate processing apparatus according to a first embodiment of the present invention.

(FIG. 2) FIGS. 2(a) through 2(d) are enlarged views showing a substrate holder, FIG. 2(a) showing a plan view, FIG. 2(b) showing a cross-sectional view, FIG. 2(c)

showing a cross-sectional view of a modification example of the substrate holder shown in FIG. 2(b), and FIG. 2(d) showing a plan view of a modification example of the substrate holder shown in FIG. 2(a).

(FIG. 3) FIGS. 3(a) and 3(b) are views illustrating an effect of a holder suction nozzle, FIG. 3(a) showing a case where a liquid is not sucked, and FIG. 3(b) showing a case where the liquid is sucked by the holder suction nozzle.

(FIG. 4) FIG. 4 is a view showing the manner in which the holder suction nozzle and a bevel suction nozzle are connected to a vacuum source.

(FIG. 5) FIG. 5 is a side view showing an arrangement of gas supply nozzles of the substrate processing apparatus shown in FIG. 1.

(FIG. 6) FIG. 6(a) is a view showing an arrangement of a plurality of gas supply nozzles; FIGS. 6(b) and 6(c) are views illustrating operation timings of the gas supply nozzles.

(FIG. 7) FIG. 7(a) is a time chart illustrating a movement speed and a gas supply (open-close) timing of the gas supply nozzle; FIG. 7(b) is a time chart illustrating a gas supply pressure and a gas supply (open-close) timing of the gas supply nozzle.

(FIG. 8) FIGS. 8(a) through 8(c) are views illustrating a flow of a drying gas, FIG. 8(a) showing a case where the gas supply nozzle is positioned at an edge portion of the substrate, FIG. 8(b) showing a case where the gas supply nozzle is positioned inwardly of the edge portion of the substrate, and FIG. 8(c) showing a case where the gas supply nozzle is positioned outwardly of the edge portion of the substrate.

(FIG. 9) FIG. 9 is a plan view showing a substrate processing apparatus according to a second embodiment of the present invention.

(FIG. 10) FIG. 10 is a side view showing the substrate processing apparatus shown in FIG. 9.

(FIG. 11) FIG. 11 is a schematic plan view showing a substrate processing system incorporating the substrate processing apparatus shown in FIG. 1 or FIG. 9.

(EXPLANATION OF THE REFERENCE NUMERALS)

(0063)

1, 1’ substrate processing apparatus

10	chamber
11	substrate holders
12, 15	cleaning nozzles
13, 14	gas supply nozzles
16	bevel suction nozzle
20	rollers
21	clamp portion
23	suction mouth
24	holder suction nozzles
25	supply mouth
26	holder cleaning nozzles
27	suction passage
29a, 29b	sponge roll type cleaning tools
31	gas-liquid separator
32	vacuum source (ejector)
33	discharge ports
71	substrate processing system
81A, 81B	wafer cassettes
82	etching apparatus
84	plating apparatus
85A, 85B	transfer robot

(NAME OF DOCUMENT) ABSTRACT

(ABSTRACT)

(PURPOSE)

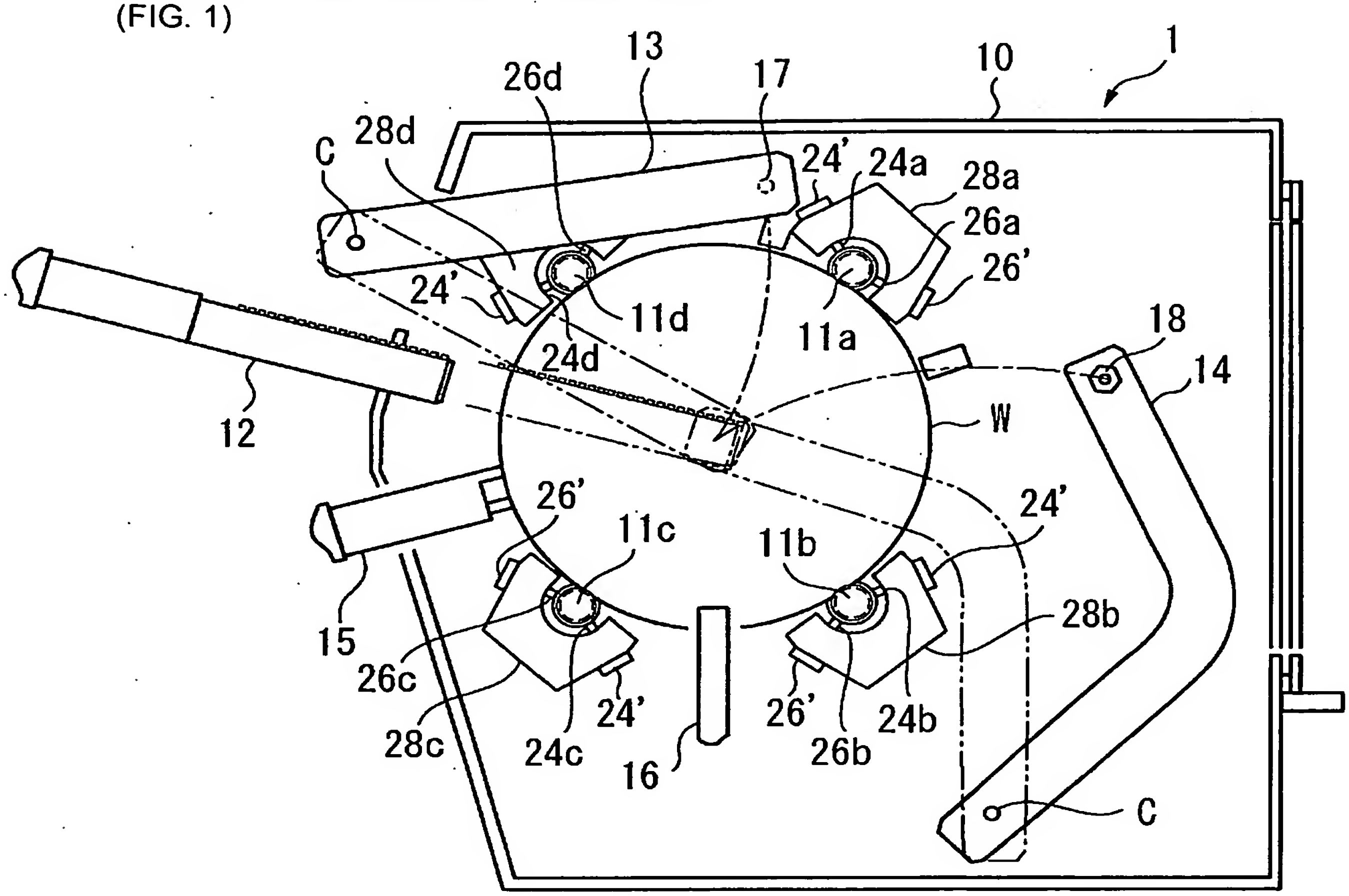
The object of the present invention is to provide a substrate processing apparatus and a substrate processing method which can prevent a fluid such as a processing liquid from being scattered from a substrate and a substrate holder while cleaning and drying the substrate, and can eliminate the remaining fluid on the substrate holder and can also accelerate replacement of the fluid.

(MEANS FOR SOLUTION)

A substrate processing apparatus is for processing a substrate W while supplying a fluid to the substrate W. The substrate processing apparatus includes a substrate holder 11 for holding and rotating the substrate W, and a holder suction unit 23 for sucking the fluid from said substrate holder. The substrate processing apparatus may further includes a periphery suction unit 16 for sucking a fluid from a peripheral portion of the substrate W.

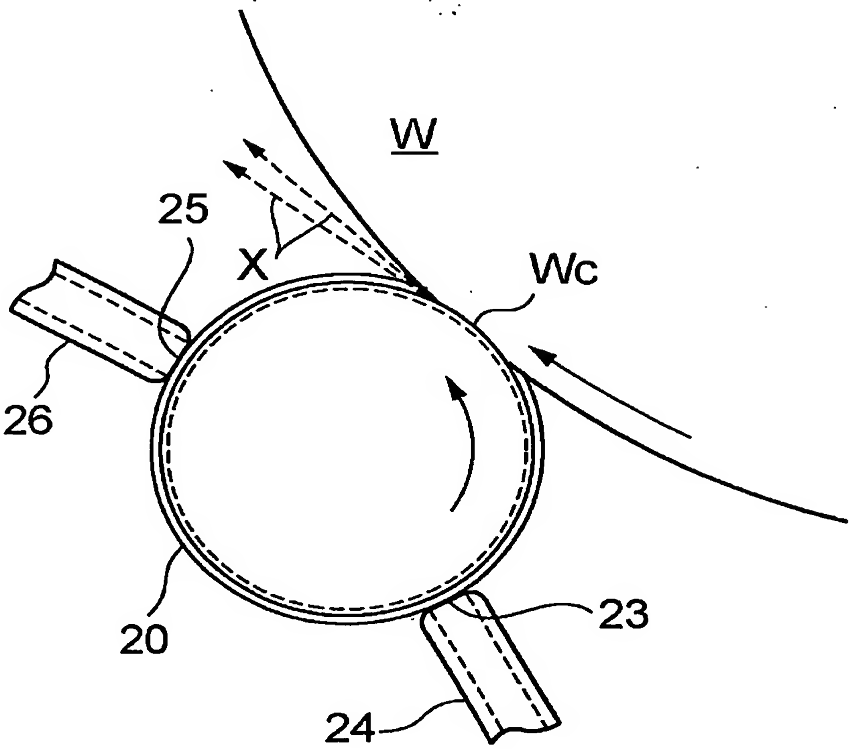
(SELECTED FIGURE) FIG. 2

REFERENCE NUMBER EB3154P
(NAME OF DOCUMENT) DRAWINGS
(FIG. 1)

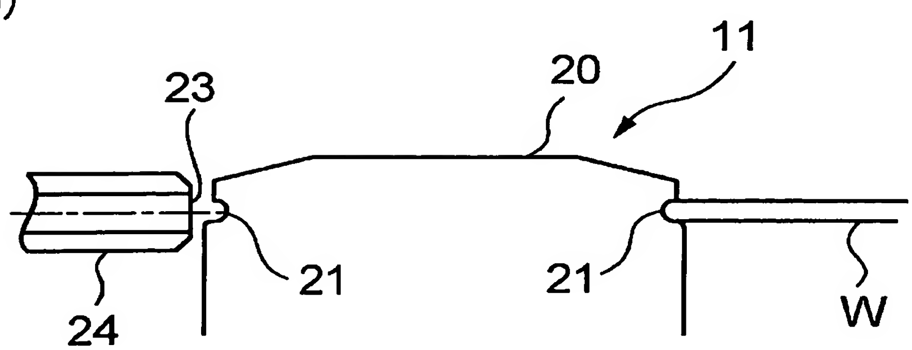


(FIG. 2)

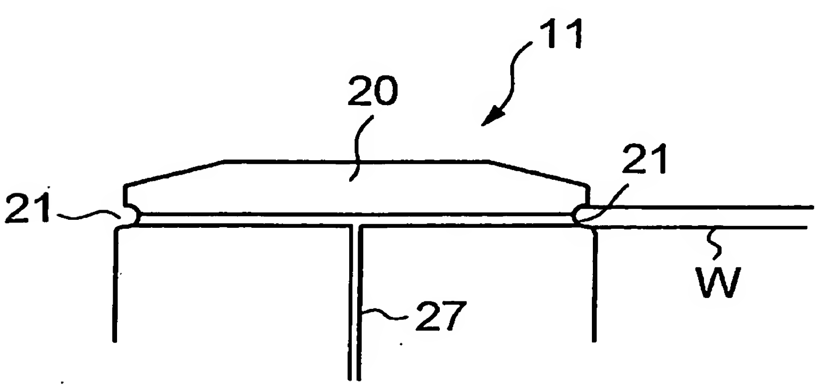
(a)



(b)

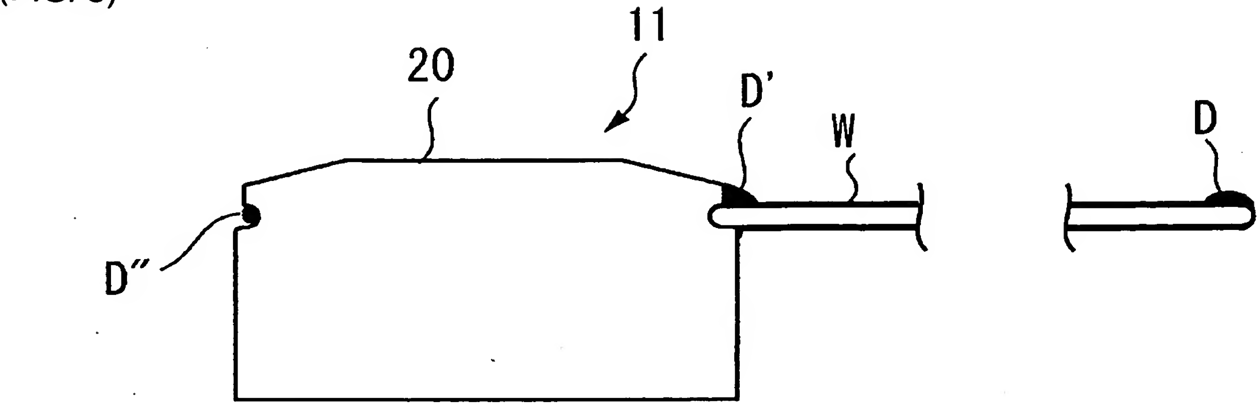


(c)

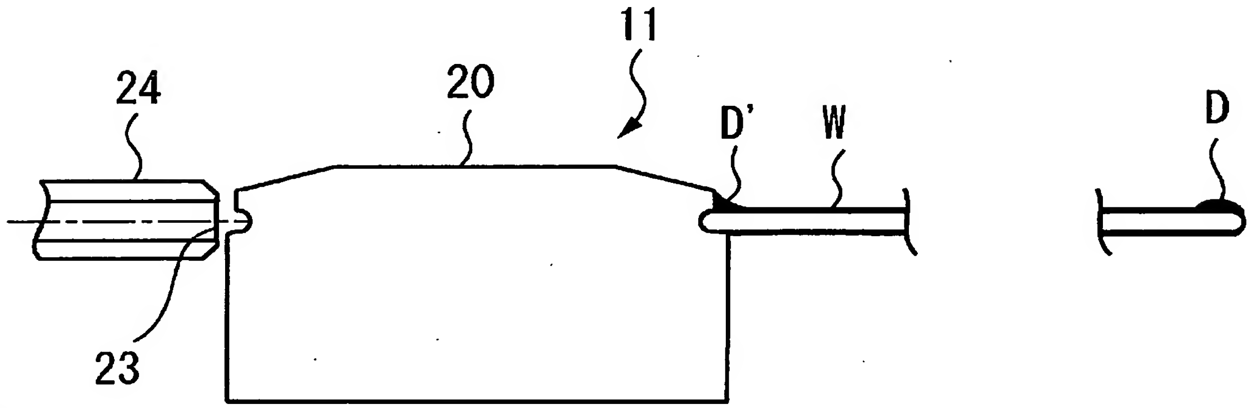


(FIG. 3)

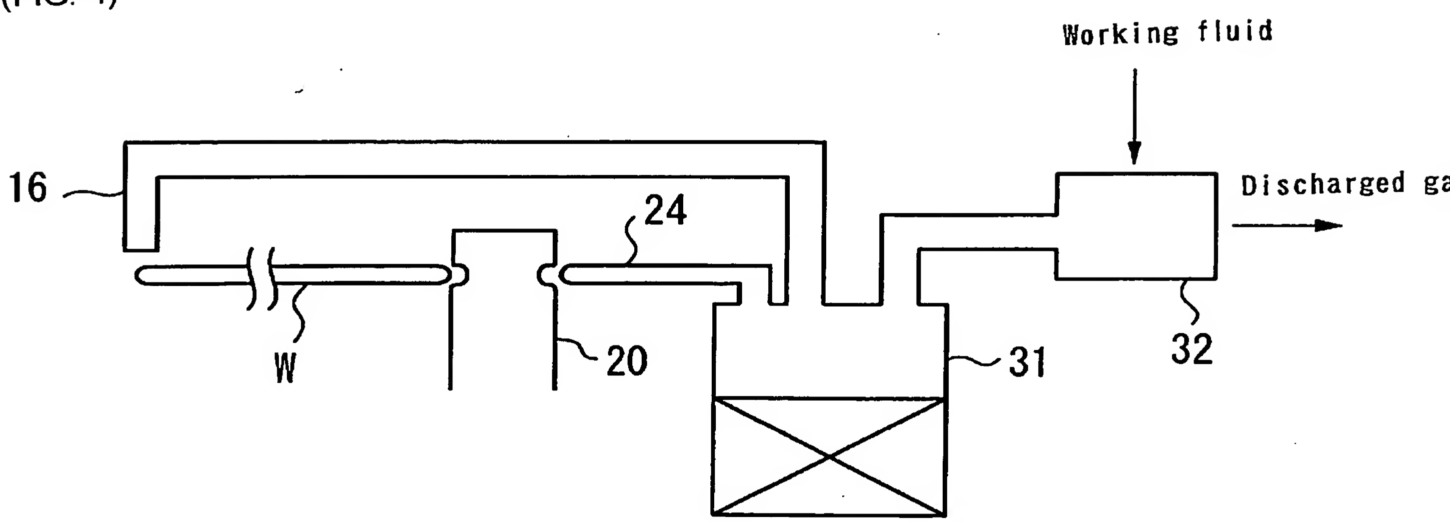
(a)


11
20
D'
W
D
D"

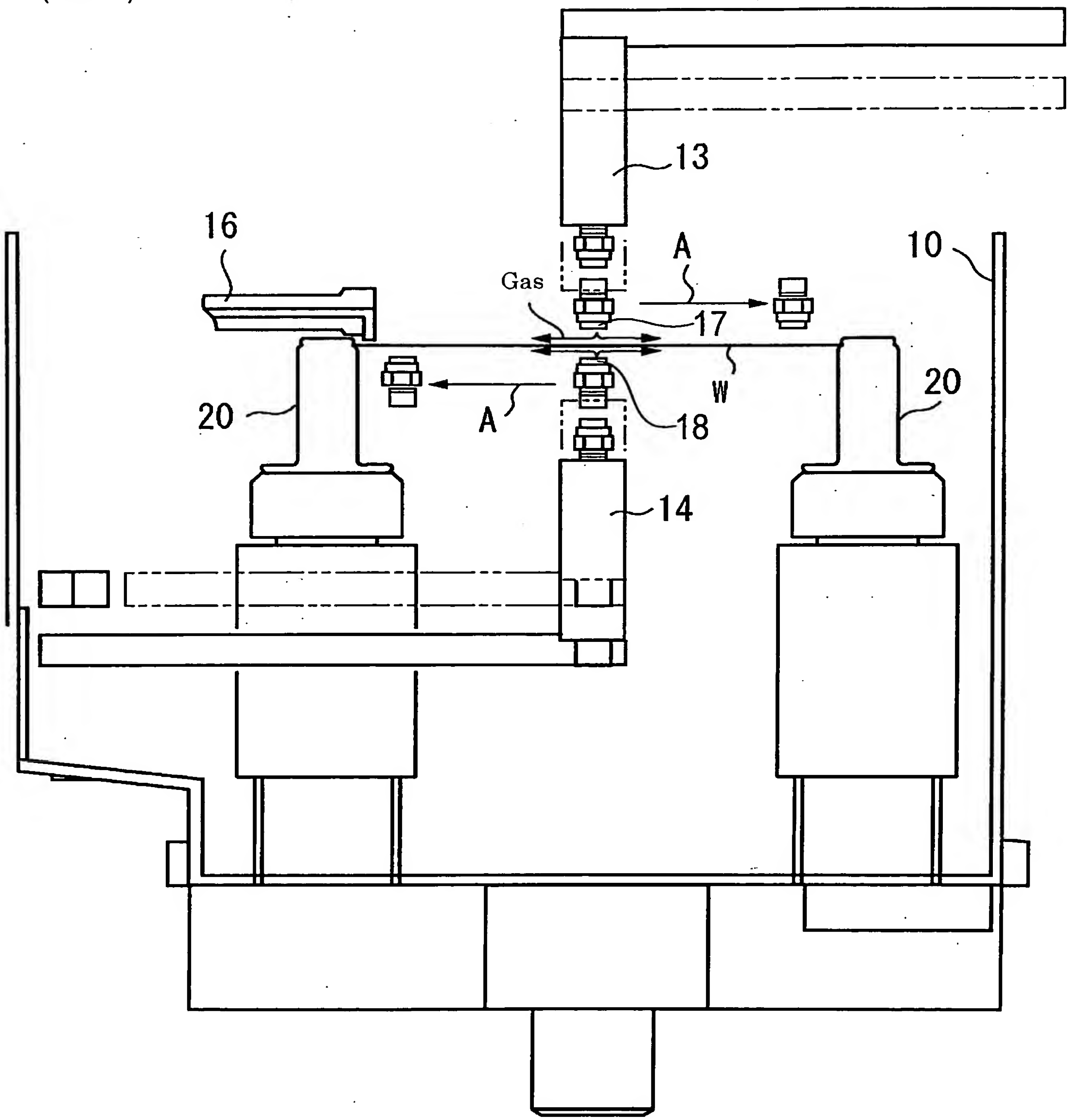
(b)


11
24
20
D'
W
D
23

(FIG. 4)

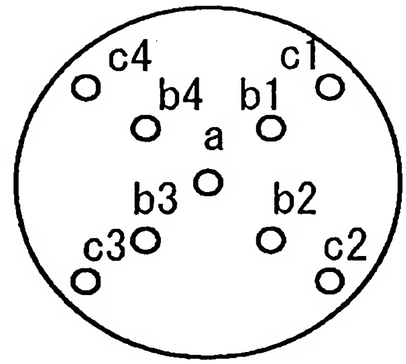

Working fluid
Discharged ga
16
24
W
20
31
32

REFERENCE NUMBER EB3154P
(FIG. 5)

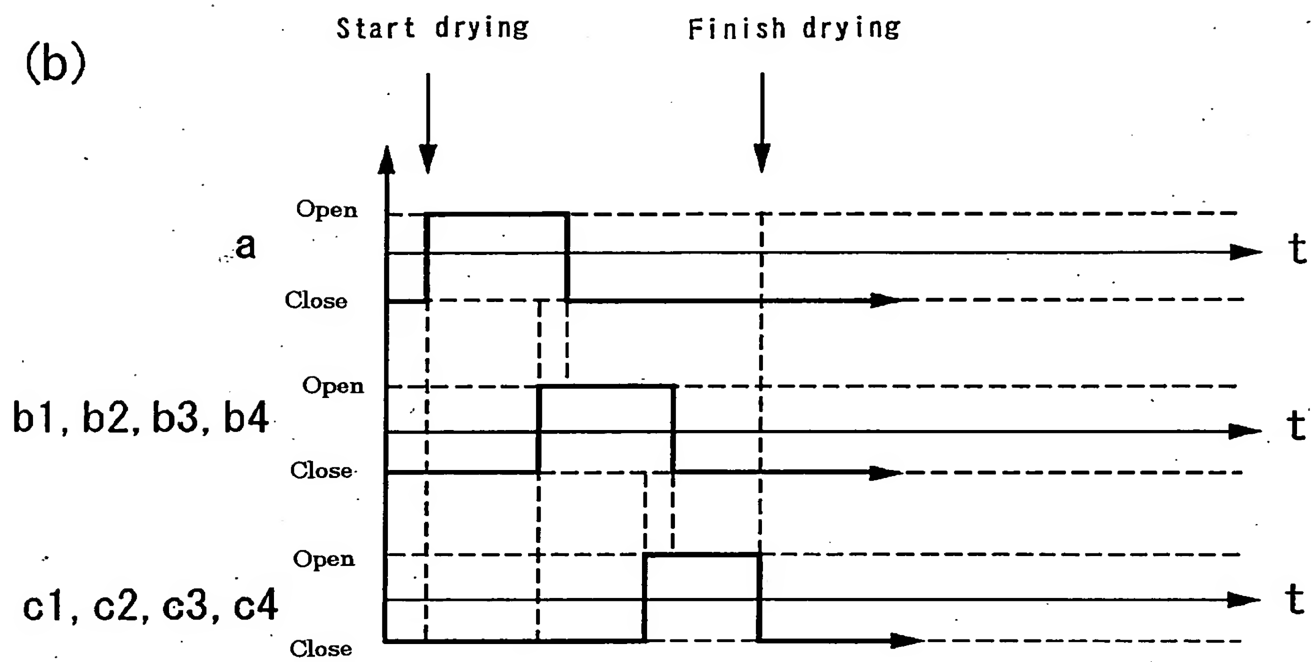


REFERENCE NUMBER EB3154P
(FIG. 6)

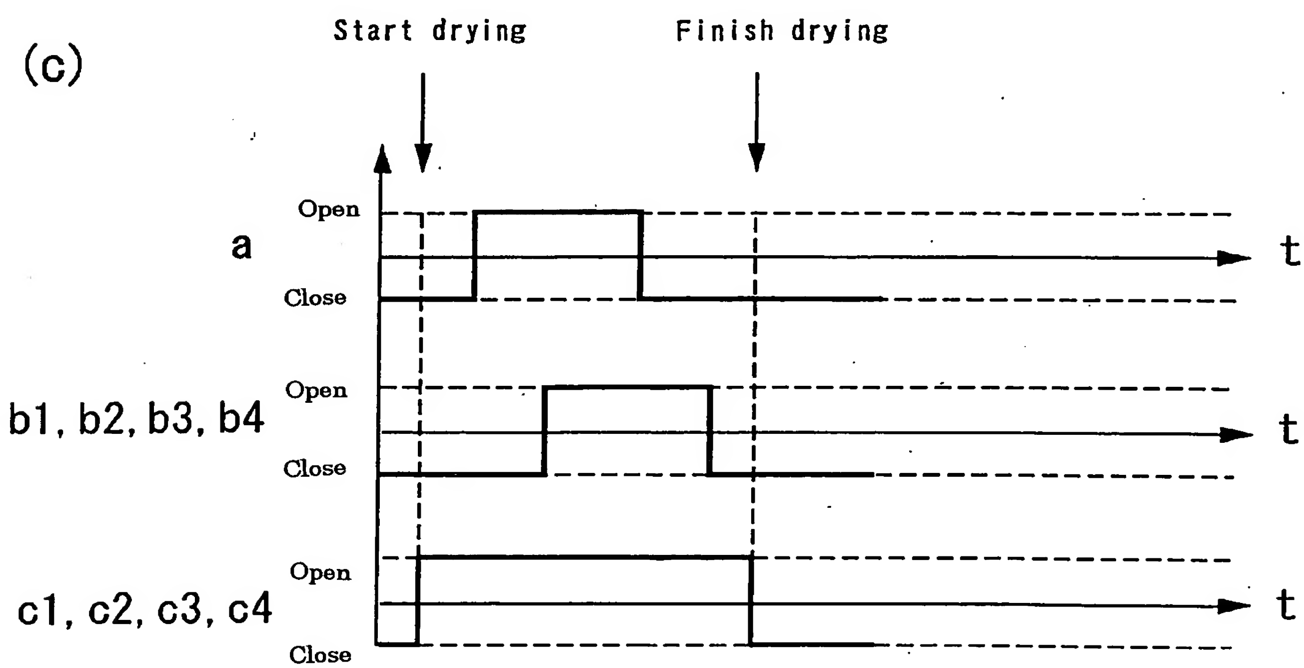
(a)



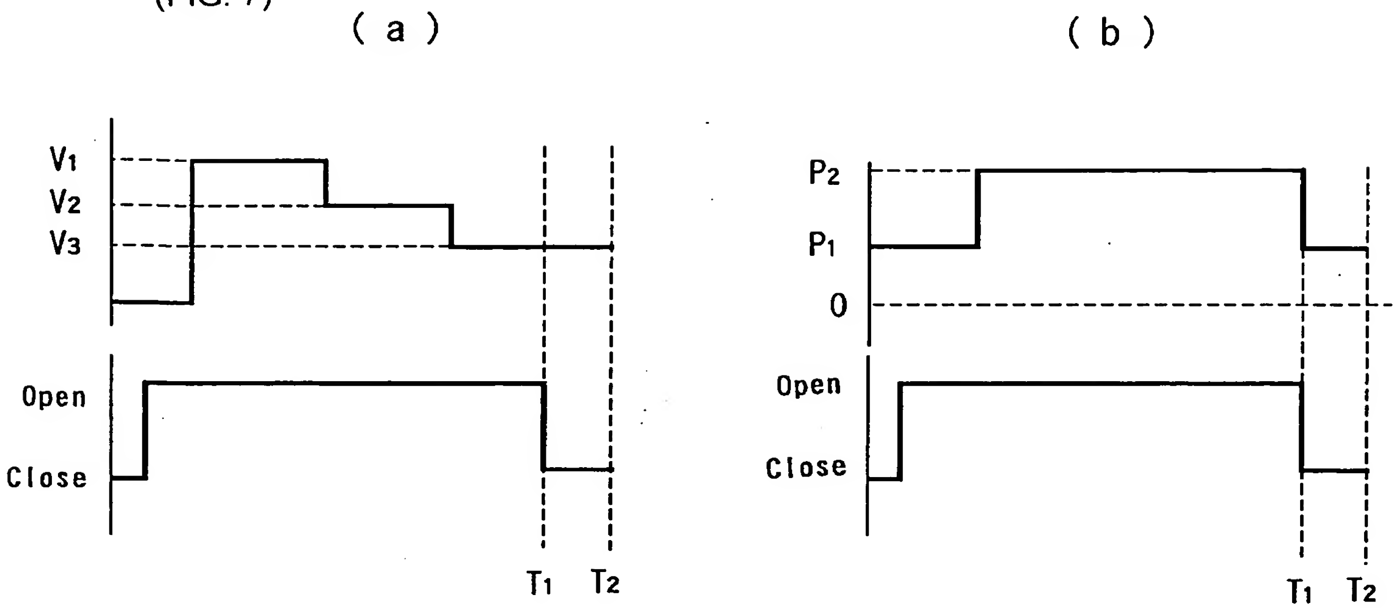
(b)



(c)

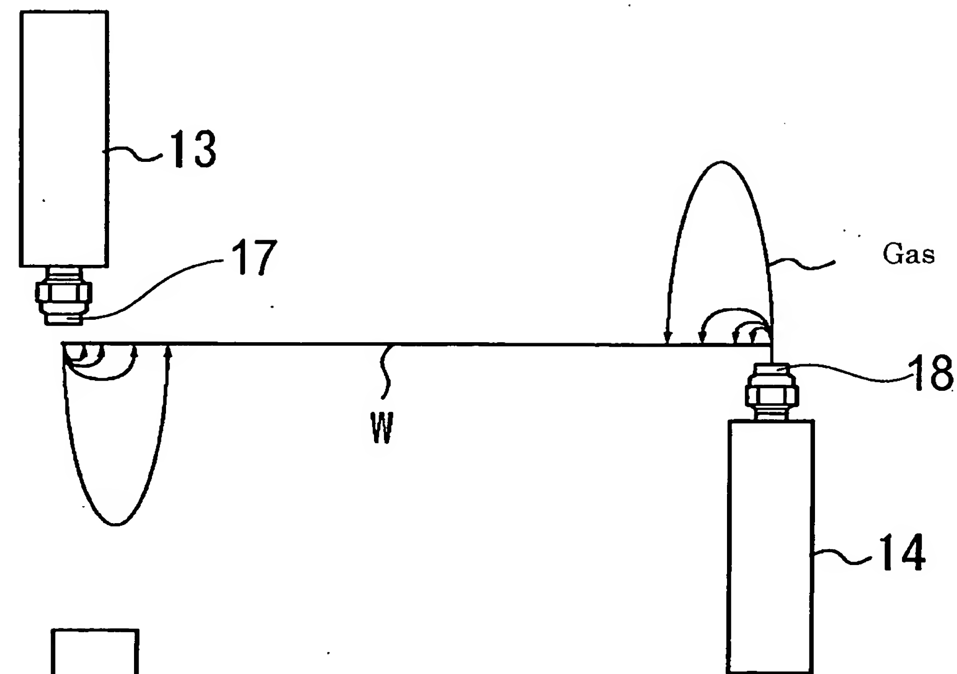


REFERENCE NUMBER EB3154P
(FIG. 7)

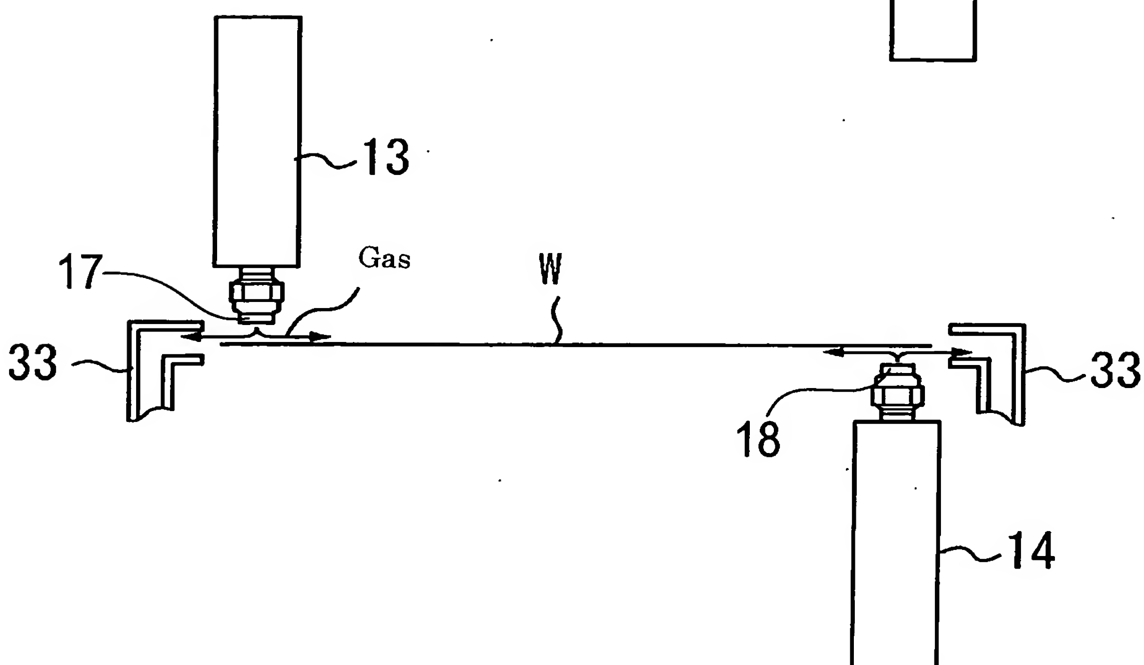


(FIG. 8)

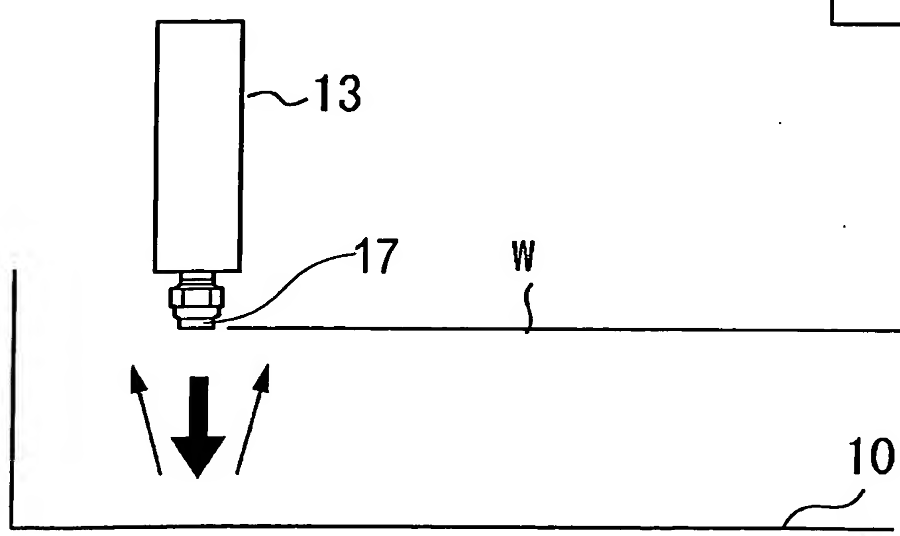
(a)



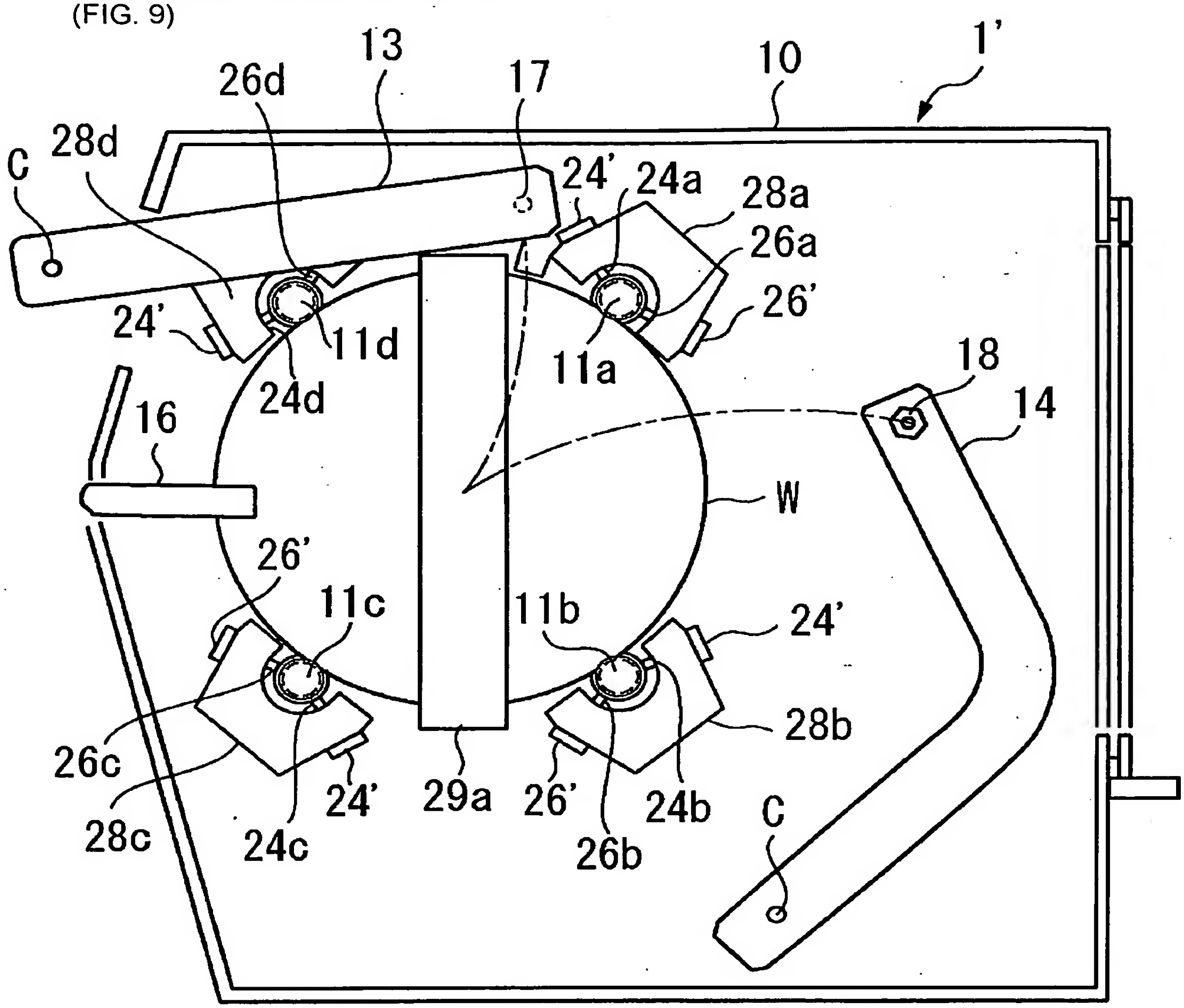
(b)



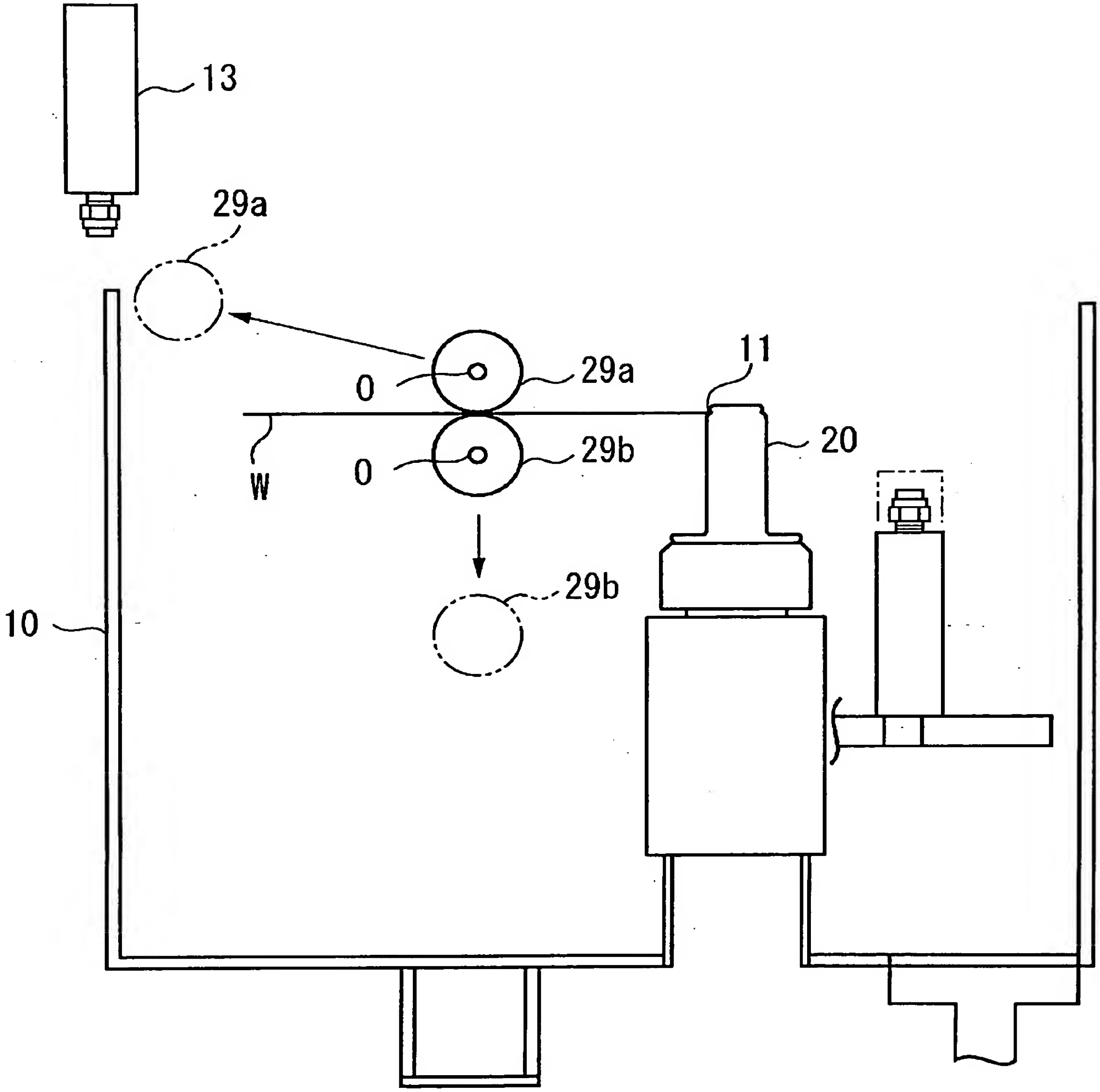
(c)



REFERENCE NUMBER EB3154P
(FIG. 9)



REFERENCE NUMBER EB3154P
(FIG. 10)



REFERENCE NUMBER EB3154P
(FIG. 11)